The Space Congress® Proceedings

1991 (28th) Space Achievement: A Global Destiny

Apr 25th, 1:00 PM - 4:00 PM

Paper Session III-C - History of the Space Based Laser (SBL) Concept Definition

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THE HISTORY OF THE SPACE BASED LASER CONCEPT DEFINITION

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ABSTRACT

The SBL system concept definition has gone through five phases. The Phase I study was from early 1982 to early 1984, the Phase II study was from late 1984 to early 1986, the Phase III study was from mid 1986 to early 1987, the Phase IV concept study was from late 1987 to early 1989, and a Special Study was performed from mid 1989 to 1990. Phase I included using a single module deuterium fluoride laser. The missions in this phase included Ballistic Missile Defense (BMD), anti-aircraft, anti-satellite, as well as negating high value ground targets. This study also examined the Command, Communication, and Control (C^3). With the advent of the Strategic Defense Initiative, Phase II primarily concentrated on the boost and post boost portion of the BMD mission for the SBL. The hydrogen fluoride (HF) laser was chosen as the baseline with a single module vs phased array configuration as trades to be studied. Phase III switched its emphasis from a far term HF device to a nearer term HF laser. The contractors also defined and assessed growth options for the HF and other devices, such as the Free Electron Laser and the Chemical Oxygen Iodine Laser, for increased performance. In Phase IV, the nearer term HF laser in a single module was chosen as the baseline for the SBL. The system was then optimized to perform the BMD mission against a formalized threat identified by SDI. The Special Study emphasized the survivability concerns for the platform and the merit of optimizing the SBL system through cost engineering. The following studies studies were assessing the impact including the midcourse mission of BMD as a potential role for the SBL.
Figure 1 shows the history timeline.

THE HISTORY OF THE SPACE BASED LASER CONCEPT DEFINITION

The Space Based Laser (SBL) system concept definition has gone through five phases. The Phase I (FIGURE 2) study was from early 1982 to early 1984. This study included using a single module deuterium fluoride (DF) laser. Phase I of the program has been devoted to conceptually defining an operational space-based laser (SBL) system, identifying the technical risks, and establishing preliminary program plans that include the activities needed for development risk reduction. The missions in this phase included Ballistic Missile Defense (BMD), anti-aircraft, anti-satellite, as well as negating high value ground targets. The four major hardware segments of the SBL system were the spacecraft segment, weapon negation capability; the surveillance segment, target and threat data; the launch and servicing segment, deploying spacecraft elements and servicing them during their operational life; and the command, communication, and control (C^3) segment. Mission utility and survivability were emphasized to assure that valid requirements were derived. A-level specifications for the baseline SBL system and its segments were established based upon mission analysis, survivability analysis and approaches, and conceptual design and system effectiveness analysis. This concept had evolved to its then present form from analysis of mission performance, survivability, concept trade studies, and life-cycle cost analysis. The spacecraft segment included defining the baseline spacecraft which was composed of laser spacecraft (LSC) and escort spacecraft (ESC) pairs. The ESC would fly in close proximity to the LSC and provide kinetic energy interceptor missile defense capability for the LSC. In turn, the LSC would provide long-range anti-satellite (ASAT) protection for the ESC. This combination offered synergistic active defense capability, while allowing the LSC to concentrate on its mission during time-stressed periods such as during the salvo launch of intercontinental ballistic missiles (ICBM). The surveillance segment was mostly composed of sensor and sensor correlation payloads in the ESCs. The space-based radar and infrared sensor (SBR/IR) would enhance the ESC sensor capability. However, mission success could be accomplished independent of this asset. The launch and servicing segment was composed of shuttle-derived vehicle (SDV) concepts, using common recoverable propulsion/avionics (P/A) modules for a SDV Inline III for LSC deployment, and an unmanned launch vehicle (ULV) for ESC deployment. The servicer was shuttle-compatible, reusable, and capable of servicing LSCs and ESCs at their operational orbits. This segment also included the integrated assembly and launch facilities. The C^3 segment consisted of three elements: the Mission Control Element (MCE), the Ground Communications Element (GCE), and the Space Communications Element (SCE). The fixed and transportable operations centers (OC) and mission control centers (MCC) comprised the MCE. The OCs were responsible for the SBLS planning, coordination, monitoring, direction, and command. The MCCs were responsible for spacecraft control, monitor, and organizational maintenance. The MCE had a support unit that provided facility, computer, and personnel support. Transportable MCEs, which were functional backups for the fixed MCE, were provided to enhance survivability and availability. National assets used included the NORAD Cheyenne Mountain Complex (NCMC) for the fixed hard MCE. Here interfaces were available for the necessary intelligence, space catalog, and early warning system data. The Consolidated Space Operations Center (CSOC) facility would conduct deployment and servicing operations with a hardline tie to NCMC to provide connectivity to the SBL commander. The SCE would provide SBL space-to-space and space-to-ground communication links. This element consisted of full-time communication nodes on each laser and escort spacecraft, space-based radat and infrared sensor (SBR/IR), high-Earth orbit communication relay satellite (SBL ComSat), and the ground-based fixed and transportable MCCs. Two nodes associated with spacecraft serving were also included: the tracking and data relay satellite system (TDRSS) and the service vehicle. The GCE included all point-to-point links. The links interconnected the SBL MCE with the NCA via the Aerospace Defense Command (ADCOM) and the NCMC, to the opetators of SBR/IR, and to supported commanders such as the Strategic Air Command (SAC). Both autonomous and interactive control provisions were embodied in the concept. Autonomous capabilities were viewed as essential for the rapid assignment of resources to specific target opportunities during ballistic missile defense. On the other hand, spacecraft and aircraft negation scenarios permited adequate time for manned interaction. Manned inhibit of the autonomous system was always possible. The baseline command and control concept envisioned the SBL mission control elements integrated into the ADCOM/SPACECOM organization. The SBL MCEs provided a single-source, integrated command and control of SBL surveillance, self-defense, and mission operations. The communications elements provided secure, highly reliable transmission and reception of target and command data from the launch of the first spacecraft of the constellation. The ESC served as the communications node of the adjacent LSC. This node received and transmited data via the SBL ComSat or the cross-link to other ESCs. Ground links were provided on both the ESCs and the SBL ComSat. A significant value of baseline mission success lied with its contribution to the survivability of other U. S. strategic forces. The baseline mission scenario was a counterforce attack on the U.S.A. with intercontinental ballistic missiles, sea-launched ballistic missiles (SLBM), and strategic aircraft carrying cruise missiles. The SBLS was required to survive the threats directed at itself; engage ICBMs, SLBMs, aircraft, and satellites; and perform the mission success criteria with a certain confidence. The baseline scenario was used to derive baseline SBLS requirements and concepts. The resulting capabilities were then analyzed. The actual numbers of the baseline concept negation and accuracy are classified. The baseline SBLS consisted of a constellation of LSC/ESC pairs. The LSCs provided the basic negation capability. The ESCs provided survivability capabilities and also served as system surveillance, communication, and battle management nodes of the SBLS.

The Phase II portion of the SBL concept definition lasted from late 1984 to early 1986. With the advent of the Stategic Defense Initiative, Phase II (FIGURE 3) primarily concentrated on the boost and post boost portion of the BMD mission for the SBL. The hydrogen flouride (HF) laser was chosen as the baseline with a single module vs phased array configuration as trades to be studied. Phase II was made up of three subphases: Phase IIA, Phase IIB, and Phase IIC. Phase IIA the Concept Formulation phase, lasted from January 1985 to July 1985. Specifically, five weapons concepts were to be developed: four from two specified classes of the HF lasers, each optimally configured in single-aperture and multiaperture arrangements: and one unrestrained by Government-defined classes. The fifth system was recommended for follow-on study in Phase IIB. Phase IIB, which lasted from July 1985 to July 1986 was a task in which the objective was to expand the weapon concept selected by the Government from Phase IIA into a weapon spacecraft concept, including interface design information relative to command, control, and communication (C^3), surveillance, and launch system segments. Phase IIC which lasted from July 1986 to September 1986 had a task that specified that innovative weapons concepts derived from advanced technologies (short-wavelength chemical and free-electron lasers) would be identified and characterized relative to that developed in greater detail in Phase IIB. Considering the Phase II conceivable technology, systems 1 snd 2 were single-aperature-class weapon modules that, when combined, became systems 3 and 4, respectively. There were two potential configurations for system 5 because it was not constrained by any Government-defined class; both single-aperture and multiaperture configurations were candidate solutions. Systems 1 and 2 were single-aperture systems; therefore, phasing applied only to the extent that the primary mirror panel segments had to be phased together. For the phased-array concepts, the concepts reflected a general trend to the two-mirror form for the smaller primaries and the three-mirror form for the larger primaries. The two-mirror form was retained for systems 1 and 2. Recommendations for system 5 ranged from thirty-seven to ninety-one subtelescopes and reflected a desire on the part of the contractors to have a design that approached diameter sizes compatible with a continuous primary mirror. Three sensor suites were postulated for acquisition and tracking for all five systems: passive infrared (IR) coarse and intermediate trackers; and an active, visible fine tracker. The coarse tracker was a separate aperature device while both the intermediate and fine trackers shared the primary optical train with the laser beam. Systems 1 and 2 employed a single three system suite. In systems 3 and 4, each aperture had three sensor suites. Full array trackers were postulated for system 5. All concepts included structural, mechanical, and optical retargeting. The major results from the Phase IIA laser device studies included the indication that the most promising concept was a master-oscillator power amplifier (MOPA) using a parallel-series coupled oscillator with multiple outlets. In Phase IIA, two MOPA concepts were considered. Concept A used a single master oscillator to drive multiple amplifiers. While this approach provided intrinsic mode control, it required a relatively high-power beam splitter and had little fault tolerance. Concept B,the second MOPA concept, used a coupled resonator with multiple outputs as the oscillator. This configuration provided a significant increase in fault tolerance. In addition, operation in the MOPA configuration significantly reduced the coupling concept power handling requirements. This concept was therefore retained for further evaluation. The two types of hydrogen flouride (HF) lasers that were considered were linear and cylindrical laser devices. The power developed in a cylindrical laser is larger than in a linear configuration of the same length by virtue of the geometry. Cylindrical devices are limited in size by the height of the nozzle, which may be fabricated, or the aspect ratio of the optical cavity. Phase IIA results concluded that a "System 5" SBL configuration involving seven modules, each with seven laser/optics channels, should be analyzed in more depth in Phase IIB. This was done in order to take maximum advantage of the Alpha and LAMP technologies. This avoided major scaling issues and more than necessary complexity. In the selected "System 5" concept, seven Alpha devices were used as power amplifiers which were arranged around the spacecraft aft-body so that the exhaust flow from each could be ducted outward. This was accomplished with the W-shaped exhaust ducts for each gain generator. Each of the seven Alpha power amplifiers fed an optical train to seven separate output telescopes. These output telescopes were conventional, on-axis Mersenne type. Each telescope in the array was gimballed to achieve a "venetian blind" pointing effect. Acquisiton/coarse tracking was done through a separate aperture tracker mounted on the outside of the telescope array. Intermediate tracking was also done through a separate aperture tracker mounted externally to the array. Fine tracking was performed through an active illuminator whose return signal was collected by the center aperture in a shared aperture mode. The outer telescopes were slaved to the center one for boresight and fine pointing control. Absolute path length control was maintained in each of the seven channels of the module. This was accomplished by an interferometric sensor approach that measures the total path length of each channel from the master oscillator to a reference point between each pair of apertures. Another set of interferometric phase sensors sampled the outgoing beams between each pair of telescopes and provided the accurate optical path difference measurements required to phase the output beams on the target. Master oscillator coupling between modules was performed to achieve the effect of a single master oscillator for the cluster. Optical path difference sensing between adjacent apertures of different modules was performed in order to properly phase the outputs from one module to the next. This single spacecraft module used seven laser and optical train channels that were mode locked and phased together to put a coherent beam on the target. These modules could be launched on orbit with projected heavy launch vehichles and could operate on their own (as a constellation) if required. In this mode, they could provide a very effective boost-phase kill capability against all but the most advanced Soviet threat.

Phase III (FIGURE 4) lasted from mid 1986 to early 1987. This phase of the concept definition switched the emphasis from a far term HF device to a nearer term HF laser. The contractors also defined and assessed growth options for the HF and other devices, such as the Free Electron Laser (FEL) and the Chemical Oxygen Iodine Laser (COIL), for increased performance. A nearer term SBL concept would have significant mission utility in both boost kill and interactive discrimination roles. Deployment of this system was designed to begin in the mid-90's using technology that could be available by that time. Phase III considered nearer term Soviet threats and associated vulnerabilities. It focused on the weapon spacecraft with an HF laser and not on the entire SBL system. This baseline SBL spacecraft was a single module scaled-up Alpha HF laser which was mounted in the aft body with exhaust ducts that were closed by doors when the laser was not in use. The reactant storage and feed system was mounted farther aft of the laser and serviceable electronics modules along with the reaction control system were mounted on the extreme aft-end. The beam expander was gimballed off the aft body with the actuator/isolator system in series to attenuate dynamic disturbances. There could be a scaled up primary mirror such as LAMP but a monolithic primary was considered feasible for this size aperture. The TITAN V was selected as the baseline launch vehicle. This selection was essentially made on the basis that both the TITAN V and the Upper Launch Vehicle (ULV) candidates had the same payload capability but the TITAN V costs were projected to be less than the ULV costs.

Phase IV (Strategic Defense Systems (SDS) phase II) lasted from early 1988 to early 1989. In Phase IV of the concept definition, the nearer term HF laser in a single module was chosen as the baseline for the SBL. The system was then optimized to perform the BMD mission against a formalized threat identified by SDI. The Hydrogen-Flouride chemical SBL was the directed energy weapon (DEW) that was studied for this phase. The mission focused on BMD using the 1987 Strategic Threat Assessment Report (STAR). The primary role of the HF laser was for defense against Soviet ICBM's and SLBM's by destroying them during their boost and post boost phase prior to midcourse phase. A SBL constellation could provide a major deterrent to the Soviet missile threat, either by itself or in combination with kinetic energy weapons (KEW's). This study characterized nearer-term HF SBL concepts for evolving BMD requirements into two types. The nearer-term HF SBL was referred to as Block I SBL and a growth version with a higher brightness was characterized as a Block II SBL. The laser device subsystem included an ALPHA-type HF chemical laser device, a fast steering mirror (FBSM #1) driven by the jitter sensor in the beam control subsystem (BCS) and a deformable mirror (DM) driven by the HEL also shown in the beam control subsystem. Survivability was a major consideration in this study. Weight and cost analysis were also done for this phase. Cost projections were made for a SBL system deployable in the near 2000's. Detailed cost analysis was performed considering two major areas: the spacecraft segment and the launch vehicle segment. The spacecraft segment included incorporating the space platform element, the laser weapon element, and a test for the spacecraft assembly, integration, and acceptance.

The Special Study Phase of the concept definition lasted from mid 1989 to 1990. The Special Study empasized the survivability concerns for the platform and the merit of optimizing the SBL system through cost and weight engineering, interfaces, performance characteristics, and sensitivities to requirements. The then current studies were assessing the impact including the midcourse mission of BMD as a potential role for the SBL. The Special Study phase had focused on an HF chemical laser that would be a logical element of a Strategic Defense System Phase II architecture. The baseline conceptual design was based on a HF cylindrical laser scaled from the Alpha technology and a segmented deformable primary scaled from the LAMP technology. The beam control system used a wide field of view, three-mirror beam expander that provided rapid, optical steering of the beam. The beam expander itself was also gimbaled with respect to the aft body to provide additional beam agility. The acquisition, tracking and pointing (ATP) system featured two passive acquisition and coarse track sensors and an active fine tracker that spectrally shared the primary mirror. Survivability was provided by nuclear and laser hardening, a protective barrel and skin over the platform, reflective baffles in the barrel, an optional companion kinetic energy DSAT, and by laser shoot-back. The SBL would be launched in a single piece and fueled on orbit by a servicing vehichle that would also carry orbital replacement units (ORU's) and an orbital maneuvering vehicle (OMV) that would affect repairs of the SBL on orbit. The reference concept is shown in figure 5.

PHASE II CONCEPTS SUMMARY (U)

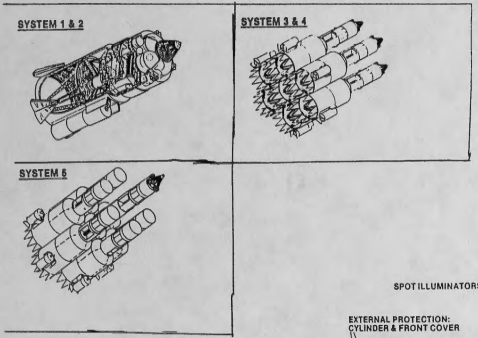

FIGURE 3

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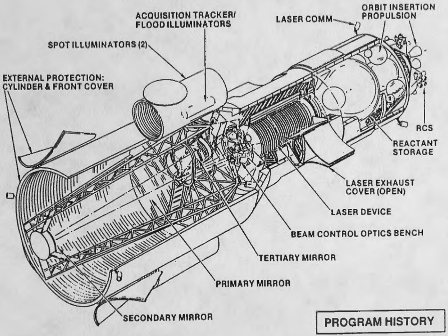
PHASE IIIA SBL CONCEPT (U)



PROGRAM HISTORY

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FIGURE 4

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SBL SYSTEM CONCEPT DEFINITION (U)

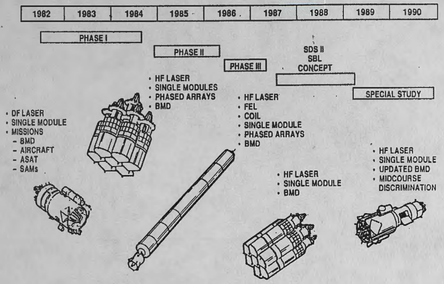

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FIGURE 1: HISTORY TIMELINE

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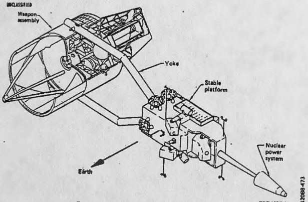

Figure 2 (U) General Spacecraft Assembly

FIGURE 2

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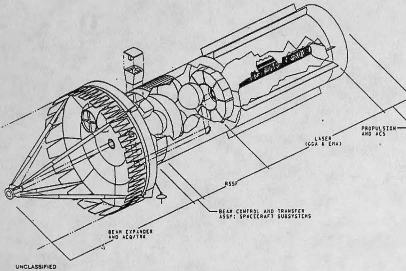

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FIGURE 5: REFERENCE CONCEPT